Parameter Estimation using Genetic Algorithms with Exact Model Evaluations[1]

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Abstract

The reconciliation of finite element models with experimental data is a computationally-intensive task which normally incorporates aspects of both sensitivity analysis and optimization theory. The objectives being optimized are usually defined in terms of differences between the modal parameters identified by experiment and those computed from the analytical model. The variables of the problem are variations in uncertain parameters of the analytical model, which might include physical design and material parameters or possibly numerical elements of the matrices representing the discretized model. In either case, derivatives of the stiffness and mass matrices are easily determined, and often these derivatives are constant with respect to the parameters for a given model form. Thus stiffness and mass sensitivities may be computed once and used in a “global” sense to compute models over a wide range of parameter variations. This is in contrast to the use of modal parameter sensitivities, which are nonlinear with respect to the parameters and thus must be recomputed during the course of a gradient-based optimization.

Our aim is to develop an algorithm which can estimate very uncertain parameters and consistently track or account for large changes in the analytical modal parameters and in the correspondence between the experimental and analytical modes. To accomplish this goal, the updated model, its response, and the computation of correlation errors must be accurately computed throughout the analysis. The resultant design space over which the optimization is being solved is both discontinuous and multi-modal. For this reason, a GA is used as the optimization engine, because of its ability to navigate such design spaces and to find globally-optimal solutions.

Table 1: GA-based Model Update Results for the Ladder Model

Experiment		Initial Beam Finite Element Model				Updated Beam Finite Element Model			
Test Mode	Frequency (Hz)	Model Mode	Frequency (Hz)	%diff Frequency	MAC	Model Mode	Frequency (Hz)	%diff Frequency	MAC
1	78.97	1	88.50	12.07	0.9967	1	78.87	-0.12	0.9978
2	170.63	2	175.05	2.59	0.9962	2	168.97	-0.97	0.9964
3	174.47	4	228.25	30.83	0.9899	3	173.94	-0.30	0.9933
4	214.72	3	219.78	2.36	0.9984	4	217.04	1.08	0.9984
5	250.91	5	268.20	6.89	0.9949	5	250.65	-0.10	0.9956
6	312.17	6	324.01	3.79	0.9804	6	311.12	-0.34	0.9924
7	315.79	8	367.81	16.47	0.9712	7	316.41	0.20	0.9815
8	317.77	9	382.56	20.39	0.9213	9	326.91	2.88	0.9597
9	330.27	7	334.66	1.33	0.9970	8	322.79	-2.26	0.9924
10	432.52	10	455.51	5.31	0.9911	10	433.91	0.32	0.9954
11	518.60	11	540.07	4.14	0.9891	11	519.10	0.10	0.9895
12	563.65	17	1052.62	86.75	0.5461	12	563.77	0.02	0.8726
13	612.81	12	633.49	3.37	0.9832	13	612.80	0.00	0.9742
14	674.36	13	731.82	8.52	0.8445	14	677.19	0.42	0.8218

Table 2: Parameter Adjustment Results for Ladder Model

Parameter	GA Search Range (relative to initial	GA Parameter Estimates	Gradient-based Parameter Estimates
$K_{\theta x}$	0.01-100.0	0.03661	0.02580
$K_{\theta z}$	0.01-100.0	.14897	.14621
I_1	0.80-1.20	0.9334	0.9415
I_2	0.80-1.20	0.9269	0.9178
J	0.80-1.20	0.9934	1.0091

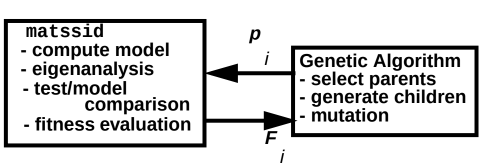

Figure 1: Interaction between GA and **matssid**

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